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Less is more – Efficient electrolysers vital for competitive Australian green iron

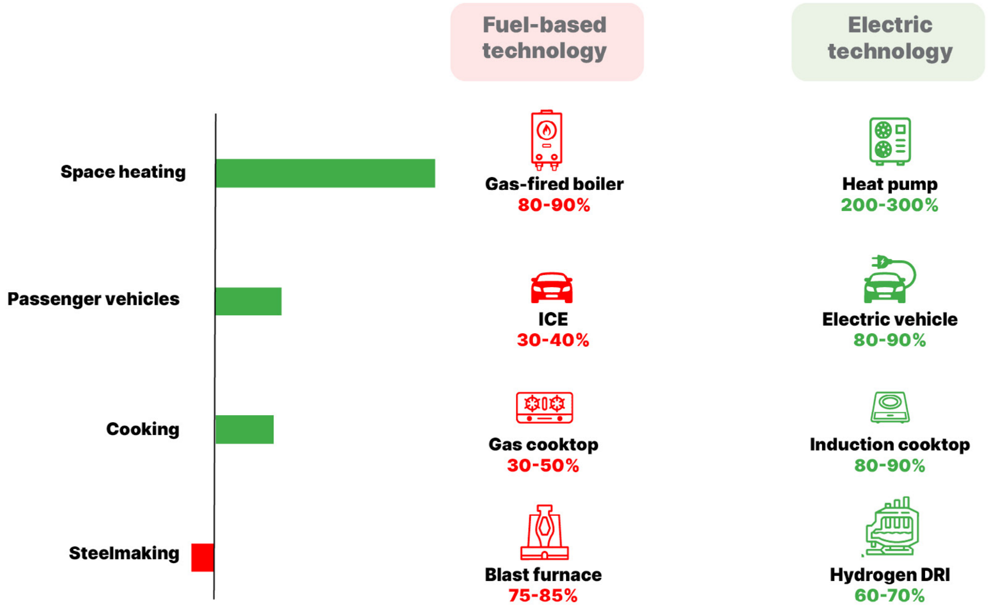
- *Energy from solar or wind is now similar in cost to gas and metallurgical coal – meaning that improving the efficiency of using electricity in steelmaking (via electrolysers) is increasingly important for cost-competitiveness.*
- *Utility-scale battery prices have dropped by two thirds since 2020, lowering the cost of firming, and shifting the emphasis towards electrolysers that offer higher efficiency rather than lowest cost.*
- *Steelmakers, iron ore producers and governments are well placed to support the development of higher-efficiency electrolysers through research and development, venture investments and industrial demonstrations.*

Australia's aim to develop a green iron export industry is based on its strength in iron ore and renewable energy, particularly solar and wind resources. As the installation costs for solar and wind have declined these two technologies have become the lowest-cost option for new electricity generation capacity in most locations.

In ironmaking there are two main uses for energy. The first is heat, to achieve the high temperatures (exceeding 700°C) needed for the reduction reaction. The second is chemical energy (usually provided by carbon and hydrogen) consumed in the reaction itself. Electricity can provide both heat and chemical energy, but the conversion (unlike electrification in other sectors) is less efficient than fossil fuel-based alternatives.

Energy from solar and wind is typically more expensive than the equivalent energy contained in a fuel. However, because conversion of fuels into electricity is inefficient (typically 30%–40%), the electricity provided by renewables is cheaper than that from fuel-based thermal generators. Even in applications where electricity competes with direct fuel use, such as in transportation, the end-use efficiency (an electric motor compared with an internal combustion engine) is greater, offsetting the higher energy cost of electricity than fuel.

Figure 1: Efficiency difference between fossil fuel and electric technologies in various applications

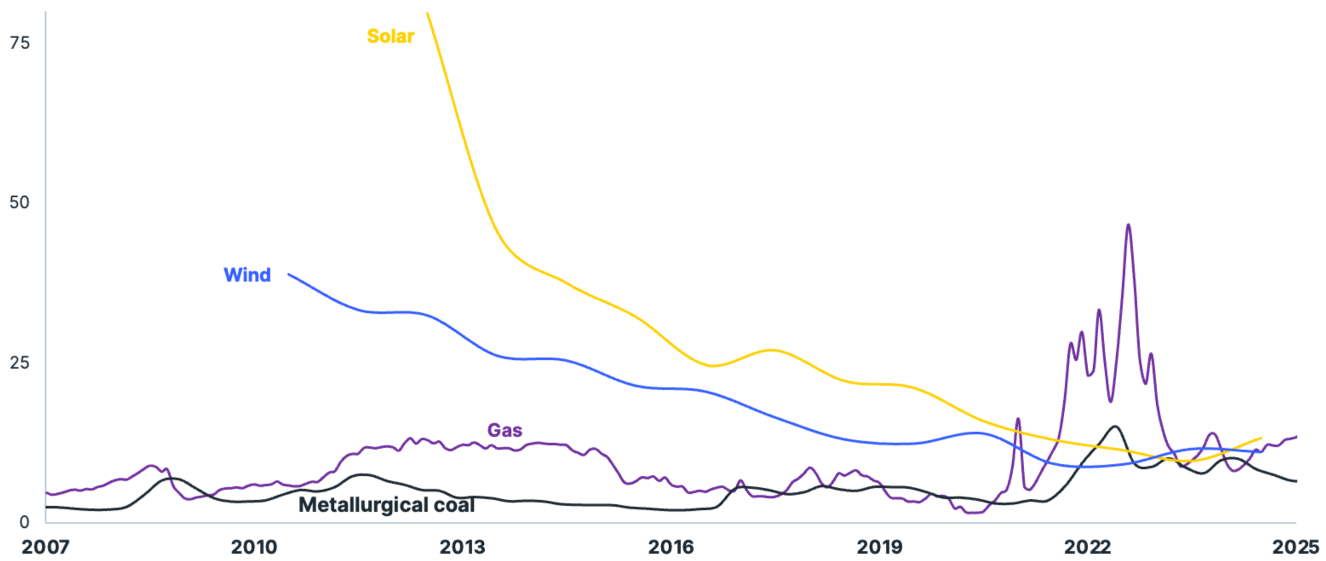


Source: US Department of Energy (Cooking, Steelmaking); International Energy Agency; US Environmental Protection Agency.
Note: ICE = Internal combustion engine; DRI = direct reduced iron.

Unfortunately, because of the energy services needed (heat and chemical) in iron and steel production, there is not yet an efficiency advantage for using electricity instead of fuel. As a result, fuels like metallurgical coal and gas have traditionally been the lowest-cost energy source. Steep declines in solar and wind costs have narrowed the gap.

As a result of recent increases in fuel prices exacerbated by the conflict in Iran and the subsequent closure of the Strait of Hormuz, renewables are now a cost-competitive source of energy, not just electricity. As a result, overcoming the efficiency deficit associated with using electricity (rather than fuels) could position renewables as the lowest-cost source to provide the heat and chemical energy needed for green iron.

Figure 2: Cost of selected energy sources for steelmakers (USD 2025/GJ)



Sources: International Monetary Fund; Department of Industry, Science and Resources; International Renewable Energy Agency.
Notes: Costs for solar and wind are Australian average exclude firming, transmission and distribution. Gas price is based on the Japan-Korea Marker. Metallurgical coal price is for premium hard coking coal from Australia.

Hydrogen headwinds

Chemical energy to drive the iron reduction reaction accounts for about three quarters of the total energy input needed for ironmaking. Hydrogen electrolysers are the most mature technology to electrify this energy requirement.

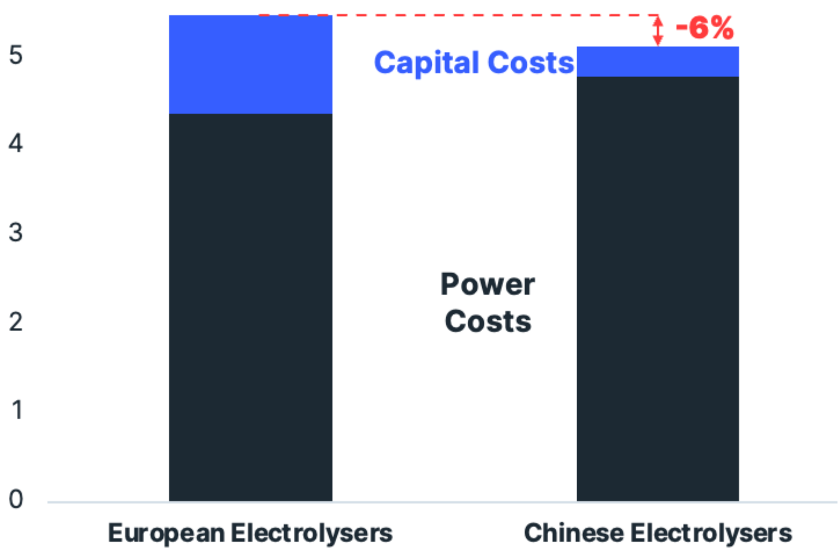
In the early 2020s, numerous forecasts predicted a steep decline in the cost to produce hydrogen via electrolysis. Most of this reduction was due to assumed "learning-by-doing" effects and economies of scale that would see electrolyser prices fall rapidly with increasing production, similar to the dynamics seen for solar PV and lithium-ion batteries. However, these forecasts did not materialise as electrolyser prices rose due to the inflation stemming from COVID disruptions. This has led to a wave of project cancellations and government funding withdrawals, including for steel projects that had planned to use hydrogen.

More important than the direct capital cost savings was the expectation that low-cost electrolysers would enable the use of lower-cost electricity (which is approximately two thirds of the overall hydrogen cost). This was premised on cheaper electrolysers enabling lower utilisation, meaning the electrolyser load could follow the profile of variable renewable output. By operating variably, the system could avoid costs for firming or grid connection, reducing the electricity price. However, with electrolyser prices now expected to stay higher for longer, this approach may no longer be feasible. Already projects which had a business model based on variable operation and cheap hydrogen storage have now seen cancellations.

The importance of electrolyser efficiency

The other way to reduce electricity costs is to use less per unit of hydrogen output – by using more efficient (rather than cheaper) electrolysers. This trade-off is already impacting the current electrolyser market. European electrolysers are more expensive compared with Chinese manufacturers but are still able to compete in the market by offering higher efficiency. At today's efficiency gap of about 6% and with a wholesale power price of USD80 per megawatt-hour (MWh), European electrolysers are competitive despite a capital cost three times higher.

Figure 3: Cost comparison between Chinese and European electrolyser supply (USD/kg H_2)



Source: IEEFA analysis; BNEF.
Note: Based on total installed capital costs of USD720 per kilowatt (kW) and USD2,300/kW and efficiency of 66% and 72% for Chinese and European electrolysers respectively and a fixed USD80/MWh power cost. H_2 = hydrogen

An electrolyser plant consists of individual electrochemical cells which are stacked (the stack level) together with supporting equipment (the system level). This support equipment includes the pumps, water treatment and electrical equipment needed to supply power and clean water to the stack, as well as the compressors and gas-liquid separators needed to remove and purify the resulting hydrogen (and oxygen).

At the stack level, inefficiencies occur either through loss of current (Faraday efficiency) or voltage (voltage efficiency). Current losses happen through multiple pathways including unwanted side reactions, leakage of produced hydrogen/oxygen across the cell membrane, or conduction pathways which bypass the cell (known as shunt currents). Voltage loss is caused by resistance resulting in electrical energy being converted to heat. An example is the formation of bubbles (of hydrogen and oxygen) at the surface of the electrodes that insulate it, leading to an increase in resistance.

Electrolysers face a trade-off between efficiency and capital costs. An electrolyser can be operated at higher electricity input (current density), which reduces efficiency but increases hydrogen output (lowering the unit capital cost). However, technology improvements can alter the relationship between those two variables – enabling higher efficiency at equivalent power input.

Manufacturers are constantly implementing these enhancements, with this trend expected to continue. These improvements include advances in electrode design and manufacturing (such as the use of high surface area sponge-like nickel alloys), as well as improved separator materials that allow for thinner designs with less resistance. A key aim for electrolyser producers and policymakers should be to increase the pace of these incremental improvements.

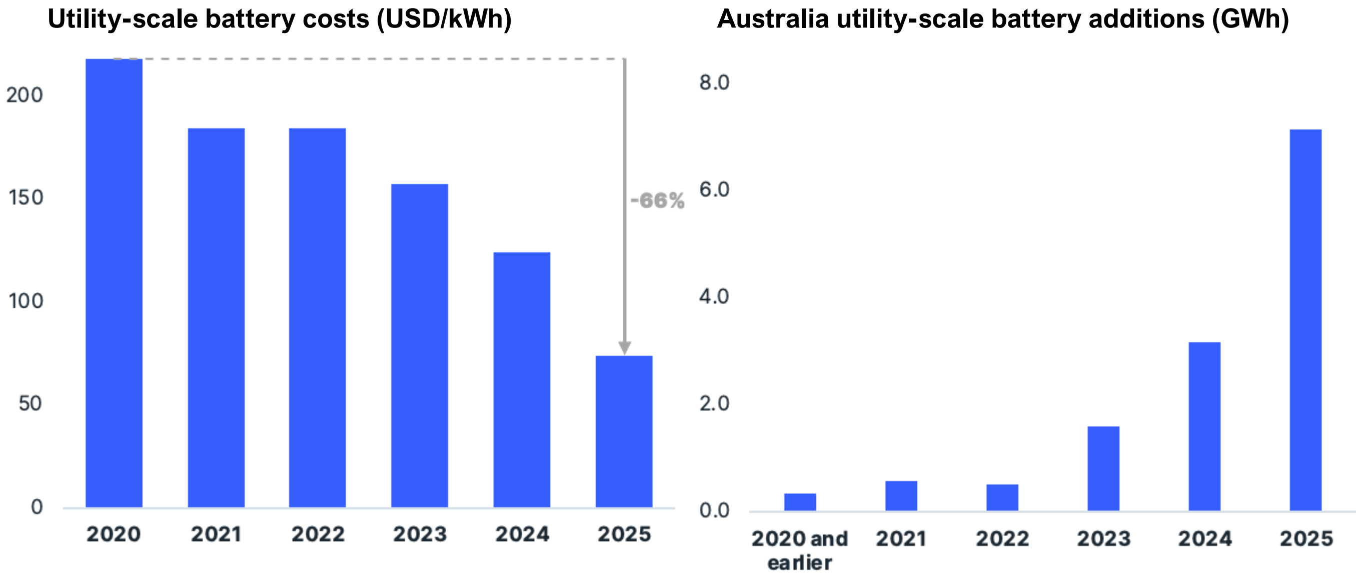
Alongside these enhancements from incumbent manufacturers, numerous start-ups are developing innovative new electrolyser designs. Many of these are focused on cost reductions (for example through avoidance of expensive catalyst materials), but several are also pursuing step-change gains in efficiency.

One example in Australia is Hysata, which is commercialising a capillary-fed electrolyser design that eliminates bubble formation, combined with an ultra-low resistance separator, to achieve 95% efficiency. The company is now working to deploy commercial-scale units both in-house and in-field with customers.

The falling cost of firming

The other major change since the start of the latest hydrogen push in the early 2020s has been the falling cost of batteries and the associated expansion of grid applications at scale. Globally, prices for grid battery storage have dropped by two thirds since 2020, while deployment in Australia more than quadrupled between 2023 and 2025.

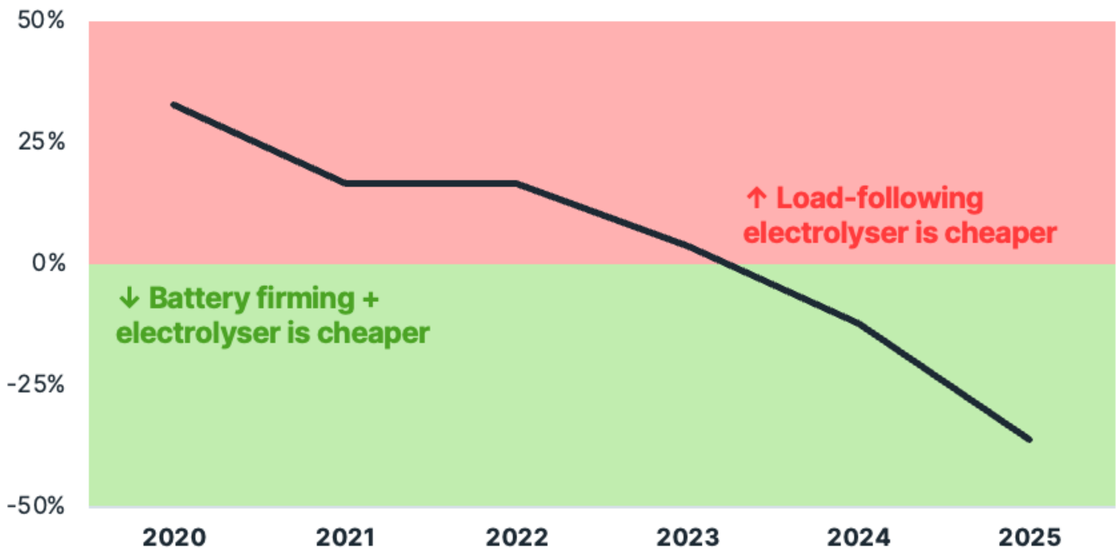
Figure 4: Global prices for grid battery storage, and utility-scale battery deployments in Australia



Source: BNEF, Australian Energy Market Operator.
Notes: Costs are volume-weighted global average in 2025 USD real terms. kWh = kilowatt-hour; GWh = gigawatt-hour.

This cost reduction means an electrolyser in load-following mode (where it dynamically adjusts its hydrogen production rate based on fluctuating energy inputs) is less competitive against a system that uses batteries to supply firmed power to the electrolyser. For example, even at the lower electrolyser prices available in China, a load-following electrolyser directly coupled to solar power is now 50% more expensive than a combined electrolyser with firming batteries producing the same volume of hydrogen. This is an important change from 2020, when the higher cost of batteries meant that electrolyser-battery systems were 30% more expensive than the electrolyser-only approach.

Figure 5: Cost difference between load-following and battery-firmed electrolyser systems (%)



Source: IEEFA analysis.
Notes: Assumes constant USD720/kW electrolyser capital cost over the period; battery prices are per Figure 4; only costs for the electrolyser and battery are considered; load profile is solar at Whyalla.

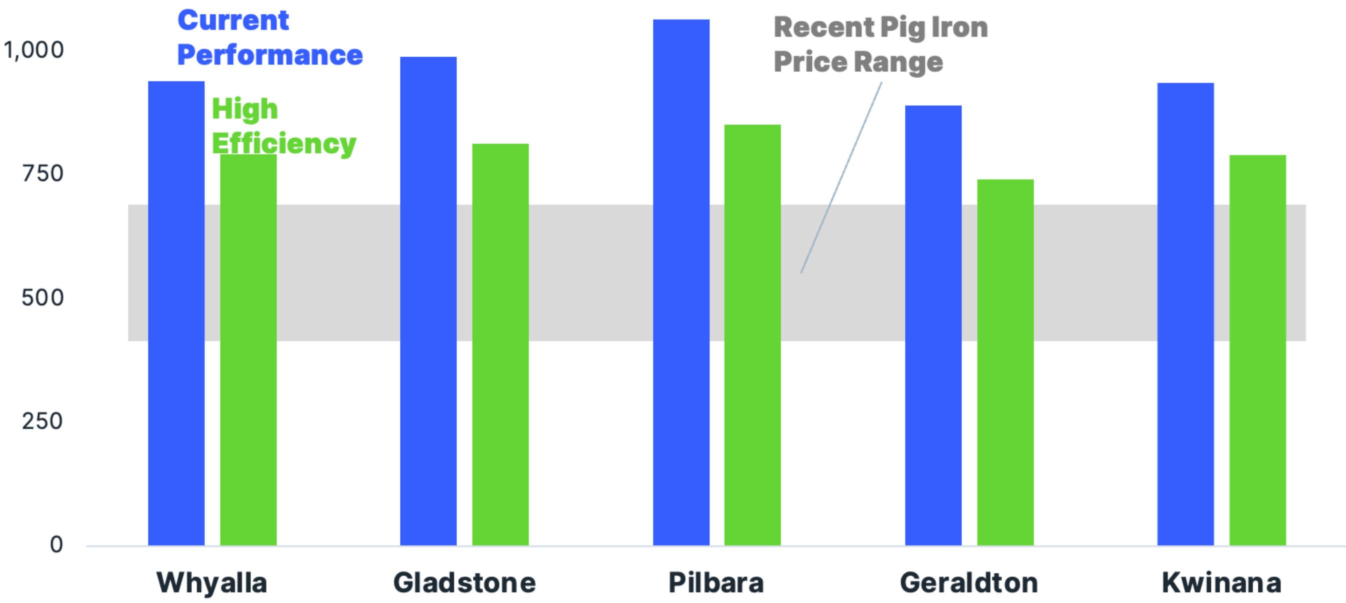
Recognising this advantage, projects and manufacturers are increasingly bundling batteries with electrolysers. For example, Engie's Yuri project under construction in the Pilbara is using a dedicated solar array coupled with a battery to supply power to an electrolyser producing hydrogen for ammonia. The world's largest green hydrogen development, the NEOM project in Saudi Arabia, is also installing a dedicated 400MWh battery system alongside electrolysers and solar. Enapter, a German electrolyser manufacturer, recently announced a joint venture partnership to provide bundled batteries in its electrolyser systems. Recent tenders for green hydrogen-based ammonia in India have also shown lower than expected prices in part because rules there allow for the use of firmed grid power.

What does this mean for Australia's green iron ambitions?

Iron and steelmakers across the world have consistently cited a lack of affordable clean hydrogen as a barrier to decarbonising production. Improving efficiency would reduce the hydrogen cost even while electrolysers prices remain high. The impact can be significant. For example, moving from today's average efficiency to the 95% level that has been demonstrated by Hysata would have an effect equivalent to reducing electrolyser costs by 60% (at an electricity price of USD50/MWh).

Most importantly for potential Australian green iron developers, having access to a high-efficiency electrolyser (even without any electrolyser cost reduction) would result in a 15%–20% reduction in the cost to produce iron depending on the location, allowing costs to approach the historical trading range for iron.

Figure 6: Levelised cost of iron production (AUD/t) at potential Australian plant locations



Source: IEEFA Analysis.
Notes: Current performance and high efficiency refer to electrolyser efficiency of 55kWh/kg of H_2 and 41.5kWh/kg H_2 respectively. Levelised cost is based on a standalone solar, wind and battery system sized to enable 90% electrolyser utilisation (hourly basis over the period of 2020 to 2024) at each location. Renewable energy/battery costs are per CSIRO GenCost 2025-26; electrolyser assumed at USD2,300/kW; installation factors scaled to Australian Bureau of Statistics data on median heavy construction labour cost by region.

But getting a highly efficient electrolyser to the market is no mean feat. First, research and development (R&D) is required to develop an approach that can significantly improve efficiency. Second, the electrolyser performance must be proven in an industrial environment. Finally, a scaled and repeatable manufacturing process needs to be implemented.

Fortunately, these challenges are well suited to steelmakers' strengths, including their ability to exert influence by working with partners in electrolyser manufacturing.

Many steelmakers, including ArcelorMittal and POSCO, as well as iron ore producers like BHP, Vale and Rio Tinto have venture investment units that take equity positions in companies developing technologies that are strategically important in the steel sector. So far, only one of these venture units (ArcelorMittal, through H2Pro) has invested in companies working specifically on improving electrolyser efficiency. Directing more investment into this area could provide significant value to these companies because of the strong influence of efficiency on hydrogen (and therefore green iron) costs.

Steelmakers can also help provide the industrial setting and testing opportunities that will be needed to prove that these advances in efficiency can move beyond lab-scale. Many operators already have experience with these types of trials, such as ArcelorMittal's use of waste biomass at Ghent in Belgium, or BlueScope's trial of solid-oxide electrolysers at Port Kembla. Conducting similar initiatives developing high-efficiency electrolysers should be a key priority for steelmakers' R&D activities.

Iron and steel producers could also come together, recognising improving electrolyser efficiency as a common challenge, and spur development of new potential innovations in the space. Similar collaborative models have been applied in other sectors, such as in mining for large-scale electric haul trucks.

Government action can also accelerate the innovation needed to improve electrolyser efficiency. Already, the Australian Renewable Energy Agency (ARENA) has provided grant funding to Hysata for a commercial-scale demonstration facility with further support also being provided to the company in partnership with Germany.

This is one of only two projects in ARENA's portfolio of hydrogen projects focused primarily on electrolyser efficiency, with most instead focused on new use-cases. The importance of efficiency in determining costs offers an opportunity to expand this R&D investment, potentially following the approach taken in solar, where ARENA has 10 active projects focused on efficiency.

Efficiency should be the focus

The electrolyser and battery markets have seen significant activity since 2020. While electrolyser costs remain stubbornly high, rapidly falling battery costs offer an opportunity to refocus on improving electrolyser efficiency. For steelmakers, this scenario means hydrogen supply is more likely to come from smaller, onsite, high-utilisation electrolysers powered with firmed, clean electricity.

Steelmakers, iron ore producers and government agencies have technical expertise and resources that can help speed up further improvements. Doing so increasingly looks critical for unlocking Australian green iron projects.

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